Systemic Illnesses Associated with Exposure to Mevinphos in California, 1982-1989

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Abstract

PISP source files contained 22,009 total reports of illness for the eight years between 1982 and 1989 and 3,626 cases of suspected exposure to one or more organophosphate insecticides. During this period there were 587 cases of suspected systemic illness reported in conjunction with exposure to mevinphos. These included 578 cases with sufficient information to judge the underlying relationship between illness and exposure; of these cases PISP files contained at least qualitative information on cholinesterase activity for 477 (82.5%). Of the 578 records with sufficient information to classify, 122 were judged as definite, 38 probable, 278 possible, and 24 unlikely or unrelated cases. Asymptomatic exposures to mevinphos, chiefly related to clusters of systemic illness, accounted for the remaining 116 cases. One hundred and twelve cases involved mevinphos as the primary pesticide exposure, and 466 involved mixed exposure to mevinphos and other cholinesterase inhibitors.

Introduction

The organophosphate (OP) insecticide mevinphos is a dimethoxy organophosphate insecticide, with an oral LD50 between 3 and 7 mg/kg,[1] currently undergoing review at the U.S. Environmental Protection Agency. This study reviews reports regarding mevinphos received between 1982 and 1989 by the California Department of Pesticide Regulation's (CDPR) Pesticide Illness Surveillance Program (PISP), evaluating current problems associated with its use and historical trends in mevinphos-related illnesses. Although CDPR has published statistics on mevinphos routinely as part of the annual PISP illness report, the criteria for classifying mevinphos and other OP related illness have varied over time and between individual reviewers.

The need for explicit criteria for categorizing illness reports derives principally from the variable relationship between reported symptoms, which are frequently non-specific,[2] and different classes of exposure. However, the potential use of the reports for regulatory purposes also requires evaluation of the quality of the available information and means of identifying pesticide-related illnesses that occurred despite adherence to existing regulations. Evaluating illnesses associated with mevinphos provides a means for evaluating the effectiveness of existing regulatory measures such as closed mixing and loading systems, use of respirators, and protective clothing.

Methods

Background

California law has required physicians to report suspected pesticide related illnesses since 1971 and jurisdiction for illness surveillance assigned to CDPR (formerly part of the California Department of Food and Agriculture) since 1974. In addition to direct pesticide illness reports (PIRs) filed by physicians, PISP cases derive from doctors' workers' compensation reports (DFRs)[a] filed with the California Department of Industrial Relations (CDIR). Individual cases reported by either mechanism are investigated locally by the County Agricultural Commissioner's (CAC) Office in each local jurisdiction. CAC investigations concentrate on the circumstances of exposure to evaluate whether possible violations of the pesticide label or the California Code of Regulations took place, but may include extensive clinical information if exposed workers give consent for release of medical records.

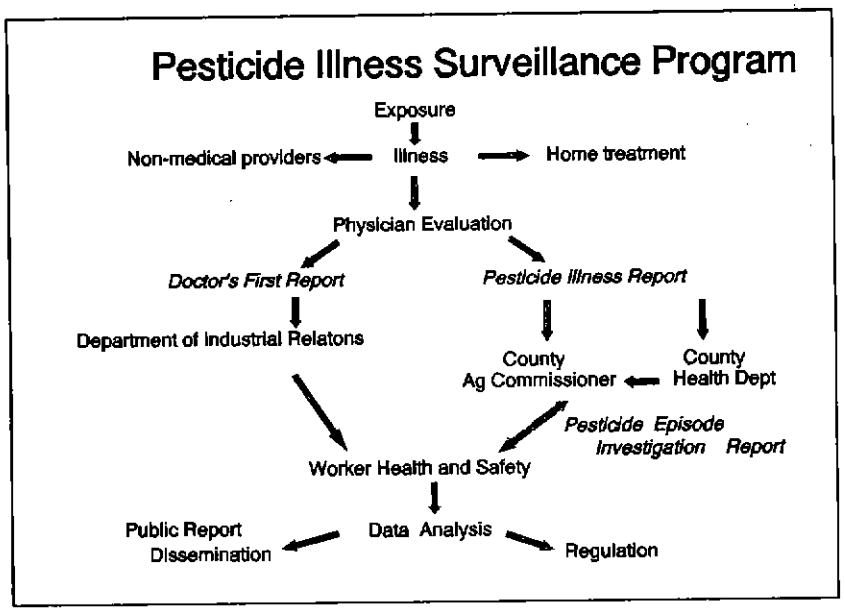

Figure 1

Cases involving 5 or more individual illness reports, a fatality, or a single individual hospitalized for greater than 24 hours receive priority in investigation. In addition to the local CAC investigation, these priority illness

a) Doctor's First Report (DFR)

cases may result in investigations by CDPR Worker Health and Safety (WHS) and Pesticide Use Enforcement staff. WHS staff review all Pesticide Episode Investigation Reports (PEIRs) for all identified cases and retain copies of PEIRs, priority episode reports, PIRs and DFRs in the Sacramento illness registry (PISP) records. Abstracted case files exist in a computerized data base for each year since 1982. Information in the abstracted case files includes the primary pesticide responsible for the reported illness (pestpri) and four additional fields used to identify other relevant pesticide exposures, type of illness (coded as fatality, systemic poisoning, eye irritation or skin case), and relationship between illness and reported exposure, days of disability and hospitalization if any, type of work activity involved, date of illness and case number of the index case in any illness cluster. No information is entered in any of the five pesticide identification fields for any case considered to be unrelated to pesticide exposure. This includes individuals exposed during an illness cluster, but who had no reported symptoms.

Extraction and review of cases

Cases were extracted from the PISP source file for each year between 1982 and 1989 based upon identification of mevinphos in one of the pesticide identification fields. Cases originally classified as unrelated to pesticide exposure were also reviewed in order to identify individuals who were part of illness clusters involving suspected exposure to mevinphos. The extraction procedure did not differentiate cases identifying mevinphos as the primary pesticide from those identifying it as a secondary exposure. Case review involved manual scrutiny of PISP files, including PEIRs, DFRs, PIRs and priority investigation reports for all cases identified from the computer source files. Information extracted included signs and symptoms of illness, exposure history, and cholinesterase data, where present. The review focused on systematic illness, but included reports of skin or eye injury, and asymptomatic-exposed individuals who sought medical evaluation to maintain complete listings of groups exposed in cluster illness episodes.

Classification of symptoms

Signs and symptoms associated with each case were reviewed in two stages in order to determine whether the clinical findings were compatible with systemic organophosphate (OP) poisoning and if so whether any specific signs or symptoms (i.e., those not usually found in common nonoccupational illnesses) were present. Within the data entry program, a partial list of compatible and a list of specific symptoms was included to facilitate the review of medical records by a data entry technician:

> *SIGNS/SXS COMPATIBLE WITH OP POISONING*: diarrhea, salivation, urination, sweating, abdominal pain, dizziness, headache, nausea, blurry vision, dyspnea, etc[b]
>
> *ENTER REPORTED SYMPTOMS*:
>
> Are reported symptoms compatible? *1=yes 2=no 3=unspecified 4=no symptoms*
>
> Are *SPECIFIC SIGNS/SXS* (miosis, salivation, sweating, involuntary urination, lacrimation, or bradycardia) present? *1=yes 2=no 3=unspecified*

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b) The data entry program did not attempt to list of all possible symptoms of OP poisoning, but focused on those most commonly found in PISP records. Several publications accurately list symptoms associated with OP poisoning (see references 3, 4, 6, and 7 as well as Morgan DP. The Recognition and Management of Pesticide Poisoning, Fourth Edition. Washington D.C.: United States Environmental Protection Agency. Office of Pesticide Programs: March 1989. Publication EPA-540/9-88-001). Sings and symptoms judged as relatively specific for OP poisoning are as listed.

Exposure Classification

Exposures were categorized to define possible means of illness prevention, recognizing that confirmed cases of poisoning occurring despite compliance with mandated safety precautions are of special regulatory significance. Below is a listing of the codes used by CDPR since 1989 for categorizing exposures to all OP compounds, in both agricultural and non-agricultural settings:

1=Direct eye/skin exposure during application/spill; i.e. direct contact with pesticide. No explicit distinction within this category is made based upon the amount of contact.
2=Exposure from outdoor drift/spill - usually inhalation exposure resulting from a distant application or spill.
3=Dermal/respiratory exposure after indoor spill - similar to category 2 except for location of spill. Not usually applicable to the use of mevinphos.
4=Vapors/odors from normal indoor application. Not usually applicable to use of mevinphos.
5=Fieldwork with normal reentry. Exposure to field residue of mevinphos. Compliance with existing waiting period for field reentry.
6=Violation of field reentry interval. Entry into a treated prior to expiration of reentry interval.
7=Normal application work/no spill. No recorded violaton of existing respiratory protection or closed system requirements.
8=Failure to use closed system/respirator/other violation documented by illness investigation.
9=Ingestion; deliberate or accidental ingestion.
10=Other; miscellaneous category includes exposures resulting from pesticide fires, cleaning and repairing of application equipment, except where an accidental direct exposure occurred.

Coding of Cholinesterase Information

Background - Blood cholinesterase assays represent a well defined biochemical means for ascertaining exposures to organophosphates.[3] Since typically reported symptoms are nonspecific, it follows that definite cases of poisoning can rarely be identified without biochemical data. For those without baseline cholinesterase tests, such as fieldworkers, careful interpretation of blood work drawn during the course of an illness is necessary. Even with appropriately chosen population normal values, there is an approximately four-fold variation in individual baseline values.[4] An additional problem is the lack of documentation for the normal ranges used by approved state labs.

The quality control program run for these labs by the California Department of Health Services (CDHS) ignores the normal values published by the labs and instead evaluates the labs' ability to detect changes in cholinesterase between paired samples (personal communication, D. Morales, Laboratory Services Division, CDHS, 1989). Thus the normal value ranges may be somewhat approximate, and should only be used as a rough way of detecting marked cholinesterase inhibition. Values in the low range of laboratory normals may sometimes represent either a true "low normal" or cholinesterase inhibition relative to an average or above average baseline value. Some type of comparison, either a baseline or a followup test taken during a non-exposed period, is therefore necessary to ascertain the true degree of inhibition.

While paired samples do provide a reasonable measure of the degree of cholinesterase inhibition, there is no specific degree of inhibition which can be used as a hard and fast benchmark for poisoning.[5] Chronic or subacute lower level exposures are apparently more readily tolerated than acute intense exposures, so that some individuals with greater than 50% inhibition are asymptomatic.[6] Following an intense exposure to a potent cholinesterase inhibitor 20-30% inhibition may be accompanied by symptoms.[7] Accurate detection of 20% inhibition may occassionally be problematic because of both physiologic intraindividual variation[8] and minor variations in laboratory technique that create artificial differences in enzyme activity between samples run at different times.[9]

The coding scheme described below aims at accurately identifying information available in the PISP records and extracting both qualitative and quantitative information regarding cholinesterase inhibition. Where present specific values of cholinesterase activity were abstracted from the records. To standardize comparisons among tests performed by different laboratory methods,[10] the midpoint of the normal range for each lab was used as the reference point for calculating % depression, following the method of Namba.[11] For individuals with either baseline or adequate followup tests, the % depression was calculated with reference to the appropriate comparison value for the individual case. In addition to abstracting individual values of cholinesterase and estimated % depression, the qualitative type of cholinesterase information was coded as shown below:

1=reported normal in the medical record or county pesticide episode investigation report; specific values not recorded
2=reported depressed; specific values not recorded
3=no test ordered or unspecified
4.0=test results available, results indicate both RBC and plasma cholinesterase are greater than the lower limits of the normal range for the lab running the assay.
4.1=test results available, results indicate either or both RBC and plasma cholinesterase are less than the lower limits of normal range for the lab running the assay.
4.2=test results available for date of illness and also a comparison baseline test; % depression calculated for both RBC and plasma cholinesterase versus midpoint of baseline;
4.3=test results available for date of illness and also a comparison followup test; % depression calculated for both RBC and plasma cholinesterase versus followup tests
4.4=lower limit of normal specified only; % depression calculated versus lower limit.
5=cholinesterase test ordered/ results not available

Criteria for classifying illness

Definite Cases *(illclass=1)* - One or more compatible symptoms, accompanied by at least a 20% decrease in plasma and/or RBC cholinesterase from non-exposed to exposed blood samples. In the absence of data from paired samples, an RBC cholinesterase or plasma cholinesterase value below the specified normal range was taken as evidence of definite illness, if accompanied by compatible symptoms.

Probable Cases *(illclass=2)* - Cholinesterase data missing or ambiguous; compatible signs/symptoms accompanied by relatively specific signs/symptoms as defined above. Cases with a history of direct exposure (exposure categories 1 or 9 as defined above) and compatible symptoms would also be considered probable cases. Cases with compatible symptoms accompanied by a qualitative report of depressed cholinesterase were also taken as probable cases.

Possible Cases *(illclass=3)* - Compatible symptoms only; cholinesterase information missing or not definitive - including samples in the normal range for which no comparison samples were available.

Unlikely *(illclass=4)* - Compatible symptoms, but cholinesterase data are negative based upon either baseline or followup samples; symptoms not compatible with illness secondary to a cholinesterase inhibitor.

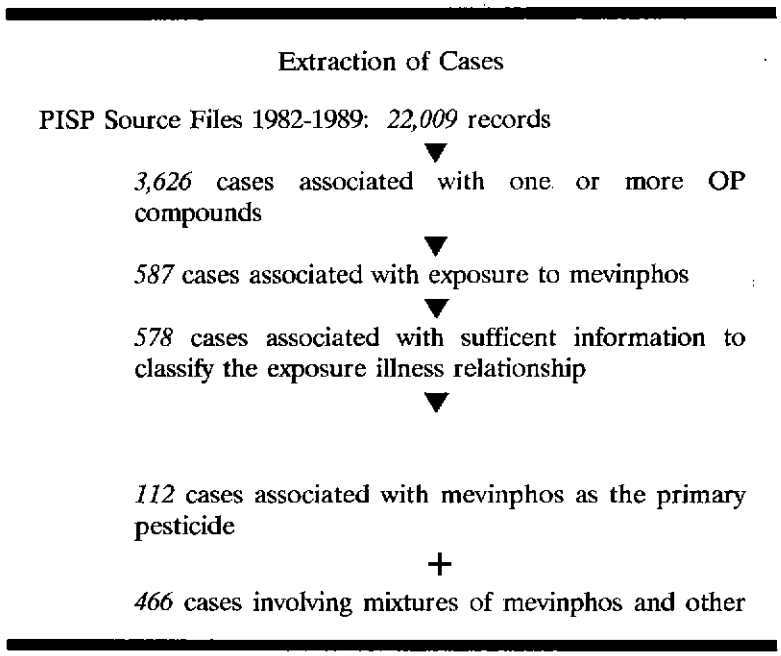
Unrelated *(illclass=4)* - Definite alternative diagnosis established.

Asymptomatic *(illclass=7)* - Exposure reported without symptoms.

Statistical methods

The SPSS/PC statistical analysis program[12] was used for analysing the coded information. Comparisons among subgroups of cases were made by calculating risk ratios, using a Yates' corrected chi-square test to evaluate statistical significance, except in cases, as specifically noted, for which an expected cell frequency was less than five, where a Fisher's exact test was used. Agreement between current and former illness classification was tested using both nominal (Kappa) and ordinal (Spearman rank correlation) measure of agreement for classification of cases in the definite, probable, possible, and unlikely/unrelated categories. This comparison excluded asymptomatic exposures (assigned unrelated status) in the former illness classification and cases not assigned an illness classification in either current or former classifications.

Figure 2



Results

PISP source files contained 22,009 total reports of illness for the eight years between 1982 and 1989 and 3,626 cases of suspected systemic illness ocurring in conjunction with exposure to one or more organophosphate compounds. During this period there were 587 cases of suspected systemic exposure to mevinphos. These included 578 cases with sufficient information to judge the underlying relationship between illness and exposure (Table 1) and 477 cases with at least qualitative information on cholinesterase activity (Table 2). Of the 578 records with sufficient information to classify, 122 were classified as definite, 38 probable, 278 possible, and 24 unlikely or unrelated cases. Asymptomatic mevinphos exposures accounted for the remaining 116 cases. One hundred and twelve cases involved mevinphos as the primary pesticide exposure (Table 3), and 466 involved mixed exposure to mevinphos and other cholinesterase inhibitors (Table 4).

Exposure Categories

Direct Exposure

Table 1 displays a breakdown of cases by illness and exposure category for the 578 cases with sufficient information to judge the relationship between exposure and illness. Of the 42 case records involving direct exposure 25 (59.5%) identified mevinphos as the primary pesticide exposure (Table 3) and 17 cases involved mixed exposure to mevinphos and other cholinesterase inhibitors (Table 4). The cases in the direct exposure classification ranged from minimal exposure to diluted mevinphos (cases 580-84 and 586-84, involving spilled tank mix from a helicopter accident; neither case involving symptoms) to cases involving massive accidental exposures resulting in marked cholinesterase depression and sometimes lengthy hospitalization (see cases 1397-88, 2033-88 and 2906-87 below).

Cases in the direct exposure category had a significantly greater likelihood of definite illness than cases in the remaining exposure categories (Risk ratio [RR]={20/42}/{102/536}=2.50, $p<0.0001$). Restricting the comparison to the 477 cases with at least a qualitative report of cholinesterase activity (Table 2), direct exposure had an even greater degree of association with definite illness (RR={20/25}/{102/452}=3.55, $p<0.0001$). The rate of definite illness for direct exposure cases did not differ significantly between the cases involving exposure to mevinphos as the primary pesticide and the cases involving mixtures of mevinphos and other cholinesterase inhibitors (RR={11/25}/{9/17}=0.83, $p>0.05$).

The listing below gives a sample of the direct exposure cases classified as definite illness:

1982-1989 Cases Associated with Direct Exposure to Mevinphos (Exposure Class = 1)

ID	Primary Pesticide	CHE Data	% RBC Dep	% PLA Dep	Ill-Class	Comment
1413-89	MEVINPHOS	4.1	76.8	NA	1	*A chemical operator sprayed with mevinphos developed symptoms of weakness, shakiness, body aches, sweating and eye twitching by the next day. Hospitalized 2 days, but was still experiencing nausea, sweating and sleeplessness 6 days after discharge from the hospital.*
1699-89	MEVINPHOS	4.1	77.2	80.0	1	*Worker was applying mevinphos to grapes without protective gear when he became ill. Symptoms-nausea, vomiting, diarrhea, abdominal cramps, excessive salivation, sweating, nervousness and shortness of breath.*
2061-89	MEVINPHOS	5.0	NA	NA	2	*Two workers siphoning liquid out of a tank that they thought contained gasoline had direct exposure to mevinphos. Symptoms-vomiting, excessive sweating, pinpoint pupils, extreme weakness, salivating, and shortness of breath. No CHE results available.*
2062-89	MEVINPHOS	5.0	NA	NA	2	*See 2061-89. Symptoms-sweating, vomiting, pinpoint, pupils, headaches, dizziness and nausea. No CHE results available.*
2066-89	ND	4.2	57.9	75.6	1	*Nozzle broke spraying worker with mixture of mevinphos, methomyl, diazinon, and xylene. Although he was wearing gloves, boots, coveralls, respirator and face shield at the time of accident, the following day he developed shakes, chills, nausea, and sweating. Six days prior to this exposure, RBC CHE levels were decreased to 18% from baseline and plasma 39%.*
2449-89	MEVINPHOS	3.0	NA	NA	2	*While loading insecticides into a truck, a can spilled, splashing him on right hand and arm. Subsequent symptoms included, chills, headache and runny nose.*
1397-88	MEVINPHOS	4.1	65.7	NA	1	*A foreman on an onion farm instructed this 57 year old worker to pour 16 ounces of mevinphos into a pump for a sprinkle irrigation system. After he pulled up the plastic spout and punctured the opposite side of the can for a breather hole, he had direct contact with the mevinphos. Symptoms included headache, numbness,*

ID=case number-year; CHE Data=qualitative description of cholinesterase data as described in text; % RBC DEP=% RBC cholinesterase depression; % PLA Dep=% plasma cholinesterase depression; Illclass=Illness classification as described in text. Abbreviations: CHE - cholinesterase; ND - primary pesticide not determined; NA - CHE results not available

1982-1989 Cases Associated with Direct Exposure to Mevinphos (Exposure Class=1)

ID	Primary Pesticide	CHE Data	% RBC Dep	% PLA Dep	Ill-Class	Comment
						nausea, and sweating. RBC cholinesterase activity proved markedly depressed and he was hospitalized because of severe bradycardia (approximately 20 beats/minute). His recovery was complicated by episodes of atrial fibrillation and he remained in the hospital for 48 days.
2033-88	MEVINPHOS	5.0	NA	NA	2	*While uncoupling a hose-during loading of a helicopter-pesticide dripped onto his pant leg. He was wearing rubber boots and gloves, and protective coveralls. Symptoms: fatigue and nausea. Pinpoint pupils noted on examination.*
1267-87	MEVINPHOS	4.1	69.9	76.9	1	*Closed system failed and sprayed mevinphos on his leg, soaking his pants. He was wearing rubber boots, gloves, coveralls, and a face shield. He changed his coveralls, but not his pants underneath which were also soaked.*
1738-87	ND	2.0	NA	NA	1	*Employee became ill while mixing and loading a mixture of parathion and mevinphos for an aerial applicator; he also had potential exposure the same day to a mixture of methomyl and endosulfan. He used a closed system for loading the insecticides, but added adjuvant through tank's lid. The lid of the adjuvant container fell inside the tank and he retrieved it with a gloved hand. About 4 hours later he developed increased salivation, and sweating, fatigue, weakness, and diarrhea.*
2115-87	ND	4.1	49.4	59.1	1	*While moving a closed mixing/loading system containing demeton, diazinon, and mevinphos, some of the material splashed on him. Later developed dizziness, headache, and vomiting.*
2408-87	ND	3.0	NA	NA	2	*While tightening a hose clamp on the mix/load system, some of the material sprayed out & hit him in the face. He rinsed his eyes, but still had eye irritation. He later experienced dizziness & nausea.*
2906-87	MEVINPHOS	4.1	74.0	64.0	1	*Worker splashed mevinphos on his face while mixing. He was wearing coveralls, rubber gloves and a respirator and promptly cleaned his face after the exposure. Three days later he developed shortness of breath, vomiting, diarrhea, and headaches. CHE was markedly depressed.*
101-86	MEVINPHOS	5.0	NA	NA	2	*During mixing/loading operation, worker spilled a small amount of mevinphos on his neck. He was wearing all proper protective clothing, but failed to immediately wash himself and became ill.*
912-86	MEVINPHOS	4.2	11.0	1.3	2	*Reportedly sprayed with mevinphos while doing an application and developed nausea within an hour after exposure.*

ID=case number-year; CHE Data=qualitative description of cholinesterase data as described in text; % RBC DEP=%RBC cholinesterase depression; % PLA Dep=% plasma cholinesterase depression; Illclass=Illness classification as described in text. Abbreviations: CHE - cholinesterase; ND - primary pesticide not determined; NA - CHE results not available

1982-1989 Cases Associated with Direct Exposure to Mevinphos (Exposure Class=1)

ID	Primary Pesticide	CHE Data	% RBC Dep	% PLA Dep	Ill-Class	Comment
2300-85	MEVINPHOS	4.1	47.4	52.8	1	*Foreman accidentally contacted concentrate mevinphos when inspecting a closed system probe without wearing protective gear. He developed nausea and began sweating 11 hours later.*
2316-85	ND	4.2	32.6	61.8	1	*Mixer/loader was splashed with liquid from tank when agitator was incorrectly turned on during process of mixing methomyl. Was wearing protective gear. Two days earlier he had reported symptoms while applying tribufos and in the interval between exposures had been mixing and loading mevinphos and several pyrethroids. He was hospitalized three days following the onset of abdominal cramping, vomiting and nausea.*
351-84	METHOMYL	4.1	33.1	84.1	1	*While applying methomyl worker felt some of the spray contact his face. He had exposure the same day to mevinphos and diazinon. About 8 p.m. he developed nausea, headache, vomiting, weakness in the legs, and passed out briefly. After his wife drove him to the emergency room, he was admitted for observation because of markedly depressed cholinesterase. Tests the day after admission demonstrated persistent depression of CHE activity.*
661-84	ND	5.0	NA	NA	2	*Applying mevinphos and methyl parathion by ground rig. Nozzles were plugged, so he tried cleaning the nozzle screens and contaminated his hands. He also had possible exposure from turning his application rig into the spray drift. Shortly after finishing work he developed nausea, vomiting and dizziness.*
1937-84	MEVINPHOS	3.0	NA	NA	2	*Warehouse worker spilled mevinphos on his leg and subsequently became 'shaky'.*
1957-84	ND	4.1	38.7	70.5	1	*Working with mevinphos, oxydemeton-methyl, demeton, and methamidphos. While mixing chemicals, he splashed some on face and became ill. Symptoms included nausea, cramps and dizziness.*
2202-84	ND	5.0	NA	NA	2	*During course of mixing and loading combinations of oxydemeton-methyl, demeton, methamidophos, and mevinphos, a leaky nozzle dripped onto worker's face and eyes. Within 15 minutes, he started to experience nausea, vomiting and dizziness. He was not wearing eye or face protection.*
1141-84	ND	5.0	NA	NA	2	*Was adjusting a hose on a spray rig containing mevinphos and demeton when it broke, and developed cramps, dizziness, and hot flashes.*
2513-84	MEVINPHOS	3.0	NA	NA	2	*Grower splashed mevinphos on his leg when opening container to mix; developed nausea and vomiting 1 hour later.*

ID=case number-year; CHE Data=qualitative description of cholinesterase data as described in text; % RBC DEP=%RBC cholinesterase depression; % PLA Dep=% plasma cholinesterase depression; Illclass=Illness classification as described in text. Abbreviations: CHE - cholinesterase; ND - primary pesticide not determined; NA - CHE results not available

1982-1989 Cases Associated with Direct Exposure to Mevinphos (Exposure Class=1)

ID	Primary Pesticide	CHE Data	% RBC Dep	% PLA Dep	Ill-Class	Comment
449-83	MEVINPHOS	3.0	NA	NA	2	*An engineer for a company manufacturing mevinphos got some of the material on his hands and washed it off. He began to experience nausea, diarrhea, and dizziness one-half hour later despite promptly washing his hands.*
517-83	MEVINPHOS	4.1	4.2	78.6	1	*Employee was moving pesticide cans in storage area and picked up an old, deteriorating can of mevinphos. After some material spilled on his clothing, he showered and changed clothes, but later developed nausea, lacrimation and tremors.*
668-83	MEVINPHOS	4.1	87.6	76.6	1	*Exposed to mevinphos concentrate while hand pouring the material into a spray tank; also exposed to diluted material while attempting to clear a clogged spray nozzle during the application. He developed nausea and vomiting several hours later.*
871-83	MEVINPHOS	4.1	40.0	80.8	1	*Was cleaning screens in the closed system without turning the pump off. Mevinphos splashed on him, but he continued loading the plane without bathing or changing clothes. He shortly became dizzy and found he could not work. He later developed nausea, dysarthria, diaphoresis, and pinpoint pupils; hospitalized for five days.*
966-83	ND	4.1	NA	96.9	1	*Removed gloves to clean nozzle while spraying bermuda grass with mevinphos and disulfoton. His hands became soaked with the tank mix; he subsequently became nauseated and began to vomit. He had pinpoint pupils and bradycardia at time of medical evaluation and was hospitalized for observation.*
1197-83	MEVINPHOS	3.0	NA	NA	2	*A grower applied mevinphos to a two acre field of eggplant using a backpack power sprayer without protective coveralls. After several hours he began to have abdominal pain, then began to vomit.*
1572-83	MEVINPHOS	5.0	NA	NA	2	*Handpouring mevinphos, worker spilled some on leg. After cleaning himself, worker was unable to find fresh clothing, and put contaminated coveralls back on. Developed weakness and dizziness soon thereafter.*
2031-83	ND	4.1	53.7	58.7	1	*Employee was adjusting boom on tractor during application of mevinphos and methomyl when leak from spray nozzle contacted face. He cleaned his face, but still began to vomit and sweat excessively.*
4-81	MEVINPHOS	5.0	NA	NA	2	*Mixing mevinphos without a closed system when he spilled concentrated material on his leg. He washed the chemical from*

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1982-1989 Cases Associated with Direct Exposure to Mevinphos (Exposure Class=1)

ID	Primary Pesticide	CHE Data	% RBC Dep	% PLA Dep	Ill-Class	Comment
						his skin, but two hours later he developed stomach cramps and cold sweats, then began vomiting.
951-82	MEVINPHOS	1.0	0.0	0.0	2	*Employee of crop dusting service reported skin contact with mevinphos while mixing loading for aerial application. Developed headache, nausea, vomiting, and muscle fasciculations.*
1333-82	MEVINPHOS	4.2	65.0	80.0	1	*Depressed CHE. -- Closed system valve malfunctioned while disconnecting fill hose. Mixer/loader developed vomiting, nausea, shaking and tingling of the hands.*
2493-82	ND	4.4	32.7	0.0	1	*While spraying mevinphos and oxydemeton-methyl, victim tore hole in glove, allowing contact with spray material. After work he began vomiting.*

Other Application Associated Illnesses

Apart from direct exposure cases application associated illnesses (exposure class=7,8) included 56 cases that followed routine application work and 20 that occurred following overt violations of regulations regarding closed systems or respiratory protection. Thirty-four (44.7%) of the 76 case records identified mevinphos as the primary pesticide exposure, and 42 (55.3%) identified mevinphos in one of the secondary pesticide exposure fields. Application associated cases had a significantly greater likelihood of definite illness compared with the remaining cases (RR={41/76}/{81/502}=3.34, $p<0.0001$). This association remained significant upon restricting the comparison to the 477 cases (Table 2) with at least a qualitative report of cholinesterase test (RR={41/56}/{81/421}=3.81, $p<0.0001$). The rate of definite illness for application associated cases did not differ significantly between cases involving exposure to mevinphos as the primary pesticide and those involving mixtures of mevinphos and other cholinesterase inhibitors (RR={16/34}/{25/42}=0.79,$p>0.05$).

The listing below gives a sample of the application associated cases:

1982-1989 Cases Associated with Mevinphos Application (Exposure Class = 7 + 8)

ID	Primary Pesticide	CHE Data	% RBC Dep	% PLA Dep	Ill-Class	Comment
946-89	ND	4.2	68.2	67.4	1	*Mixer/loader and cleaner/repairer experienced dizziness, headache, vomiting, muscle weakness, and constricted pupils after 6 weeks working for a crop dusting service. Exposures included oxydemeton-methyl, mevinphos, methamidophos, acephate, dimethoate, oxamyl, and methomyl.*

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1982-1989 Cases Associated with Mevinphos Application (Exposure Class= 7+ 8)

ID	Primary Pesticide	CHE Data	% RBC Dep	% PLA Dep	Ill-Class	Comment
1351-89	ND	4.1	74.8	90.6	1	*Worker mixed/loaded, applied and unplugged nozzles and hand poured mevinphos and dimethoate without wearing protective equipment. Although he was driving a tractor with an enclosed cab, the air conditioning did not work and he left the windows open. Symptoms-abdominal pain, cramping, multiple muscle fasciculations throughout thighs and calves.*
1775-89	MEVINPHOS	5.0	NA	NA	3	*A grower was applying mevinphos to his vineyard when he began to experience vomiting, weakness, diarrhea, and sleepiness despite reported use of appropriate safety equipment.*
1776-89	MEVINPHOS	5.0	NA	NA	3	*See reference case 1775-89. Symptoms included vomiting, weakness, loss of vision, diarrhea, and sleepiness.*
1778-89	ND	4.1	61.1	93.1	1	*Over the 30 days prior to his illness, mixer/loader worked 206 hours with various organophosphates and carbamates. These included azinphos-methyl, parathion, methomyl, malathion, carbaryl, mevinphos, diazinon, dimethoate, and chlorpyrifos. The day of his illness, he had been mixing for 9 hours prior to onset of nausea, vomiting, muscle weakness, cramps and dyspnea.*
1814-89	MEVINPHOS	4.1	80.6	85.7	1	*Worker was hand pouring as well as spraying mevinphos using open pour technique. Was wearing gloves, goggles, respirator, and raingear. Developed vomiting, weakness, and nausea..*
1824-89	ND	4.1	95.0	91.1	1	*Mix/loader developed muscle twitching, diarrhea, headaches, perspiration, hypertension. Mixed category 1 materials, including methomyl and mevinphos, without a closed system, but reported wearing rubber boots, gloves, coveralls and respirator. CHE levels depressed approximately 50% of baseline 10 days prior to onset of illness.*
2225-89	MEVINPHOS	4.2	65.9	69.9	1	*Employee mixing and loading mevinphos developed nausea, vomiting, weakness, blurred vision and pinpoint pupils while training another employee in use of closed loading system. Supervisor reported that exposure may have resulted from employee opening lid of mix tank to check liquid level inside. Medical records describe worker as "pouring chemical" for three hours prior to onset of symptoms.*
2360-89	ND	4.1	90.0	74.4	1	*A worker suffered nausea, vomiting, abdominal cramps, pinpoint pupils and bradycardia following mixing/loading/applying mevinphos. A closed system was used during the mixing/loading operation and he reported that he wore appropriate protective equipment. During hospitalization he showed clinical response to*

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1982-1989 Cases Associated with Mevinphos Application (Exposure Class= 7+ 8)

ID	Primary Pesticide	CHE Data	% RBC Dep	% PLA Dep	Ill-Class	Comment
						atropine and marked cholinesterase depression, but he was also found to have a peptic ulcer.
2460-89	MEVINPHOS	3.0	NA	NA	3	*Chemical pumper at a chemical manufacturing plant developed chills, sore throat, headache, and nausea. He presumed his symptoms were due to mevinphos, but did not recall specific exposure.*
252-88	ND	5.0	NA	NA	3	*Mixer/loader was preparing a load of mevinphos and carbofuran for an application to alfalfa, wearing rubber boots, gloves, respirator, coveralls and a face shield and using a closed system.*
1630-88	ND	5.0	NA	NA	3	*Mixer/loader worked long hours handling acephate and mevinphos and began to feel dizzy, nauseous and weak.*
1937-88	MEVINPHOS	2.0	NA	NA	3	*Developed dizziness, abdominal pain, nausea, and vomiting while applying mevinphos despite use of goggles and respirator. Worker reported that he did not know how exposure occurred. CHE reported depressed, but specific results not available.*
1998-88	ND	5.0	NA	NA	2	*Mixing pesticides including methomyl, mevinphos, diazinon, and ethion, when he developed blurry vision, weakness, and fatigue. He later developed sweating and fever-like symptoms. Used all safety equipment required.*
2051-88	MEVINPHOS	4.0	NA	NA	3	*Worker developed shortness of breath and burning sensation in chest, the day after spraying and supervising spray of mevinphos in an orchard. He was wearing a respirator, coveralls, boots, gloves and apron. CHE within normal range, but no baseline value reported.*
2253-88	ND	5.0	NA	NA	2	*Complained about dizziness, lightheadiness, blurred vision after working with mevinphos, methomyl, and endosulfan. Wore coveralls, rubber gloves and boots, and respirator.*
245-88	ND	4.1	47.3	50.9	1	*After hand pouring mevinphos and disulfoton developed symptoms of dizziness, vomiting, headache, nervousness, and muscle twitching.*
433-88	ND	4.1	43.6	NA	1	*Applicator showed depressed cholinesterase from routine testing. Safety equipment provided and worn, but he reported only intermittent use of closed mixing/loading system. Symptoms included headache, diarrhea, fatigue and blurred vision.*

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1982-1989 Cases Associated with Mevinphos Application (Exposure Class= 7+ 8)

ID	Primary Pesticide	CHE Data	% RBC Dep	% PLA Dep	Ill-Class	Comment
908-88	ND	4.2	75.7	71.9	1	*Developed nausea, dizziness, and vomiting after using a closed system to mix/load various pesticides, including mevinphos and methamidophos.*
1402-88	MEVINPHOS	4.1	80.0	78.4	1	*Mixing and loading mevinphos using a calf feeding bottle and applying with a hand held sprayer onto watermelons when he developed vomiting, clammy skin, excessive salivation, abdominal pains, pin point pupils, and dizziness.*
1439-88	MEVINPHOS	4.1	62.4	80.7	1	*While mixing/loading mevinphos, worker developed nausea, dizziness, and vomiting, despite reported use of closed system and all required safety equipment.*
1489-88	ND	4.2	66.4	87.4	1	*Loading mevinphos, methomyl, and methamidophos, he experienced weakness, nausea, vomiting, and blurred vision, although he reportedly used closed system, respirator, face shield, rubber gloves, boots, and coveralls.*
1619-88	METHOMYL	3.0	NA	NA	2	*After finishing mixing and loading methomyl in water soluble bags, he removed respirator & possibly inhaled some of the material. He also worked with mevinphos, chlorpyrifos, and profenofos. He developed symptoms nausea, vomiting, diarrhea, headache, and cramps; symptoms responded to atropine in hospital.*
2009-88	MEVINPHOS	4.1	82.0	65.6	1	*Mixer/loader developed sweats, weakness, nausea, and vomititng after mixing two loads of mevinphos. Wore gloves, face shield with positive pressure helmut, and coveralls, but had a three inch gap between coveralls and gloves.*
2045-88	ND	4.2	77.7	97.5	1	*Worker developed weakness, blurred vision, nausea, vomiting, tiredness, excess salivation and dizziness while mixing and loading mevinphos, methomyl and methamidophos. He reported wearing coveralls, respirator, rubber gloves, boots, and goggles and using a closed system.*
2145-88	ND	4.1	27.8	0.0	1	*Worker was applying methidathion and mevinphos when he began to smell materials through respirator. He developed dizziness, nausea, and fatigue. He was wearing full protective clothing and reported that he changed respirator cartridge every day.*
2212-88	ND	4.2	66.0	81.0	1	*While mixing/loading & applying oxamyl, methomyl, mevinphos, and oxydemeton-methyl, employee developed nausea, blurry vision and cramping. He wore a face shield, respirator, gloves, coveralls and boots and used closed system.*

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1982-1989 Cases Associated with Mevinphos Application (Exposure Class= 7+ 8)

ID	Primary Pesticide	CHE Data	% RBC Dep	% PLA Dep	Ill-Class	Comment
3098-88	ND	4.1	79.0	79.0	1	*Mixer/loader developed cold sweats, nausea, vomiting and pinpoint pupils after finishing his shift working with mevinphos, formetanate HCL, and demeton. He went to the hospital, was given 2 shots of atropine and returned home. He got sick again when he returned to work (2 days later). Worker had hand poured category I materials because closed system did not work.*
1421-87	ND	3.0	NA	NA	2	*Worker was mixing and loading mevinphos and dimethoate for an aerial application; medical records report exposure occurred when he removed respirator and accidentally breathed fumes from a spent container. Illness investigation report indicated he was wearing all appropriate safety gear and using a closed system for mixing and loading.*
1166-87	ND	4.0	0.0	0.0	2	*Aerial mixer/loader hand poured mevinphos, carbofuran, and disulfoton without a respirator, but was wearing all other required protective clothing. During the 3rd mix/load he developed nausea, sweating, diarrhea, vomiting and weakness. Medical examination also showed pinpoint pupils and he was hospitalized for 1 day.*
1716-87	ND	2.0	NA	NA	3	*Worker put his head in a tank mix of mevinphos, diazinon, methomyl, and endosulfan to check the water level, while wearing a respirator, coveralls, rubber boots and rubber gloves. Approximately 30 minutes later he developed vomiting, dizziness, and shaking.*
2180-87	MEVINPHOS	4.1	87.3	45.8	1	*Mixer/loader routinely wore a repirator, rubber gloves and boots throughout the application season. After 5 months, working principally with mevinphos, but also with parathion and other CHE inhibitors, he developed blurred vision and drowsiniess.*
69-84	ND	2.0	NA	NA	7	*Mixer/loader's CHE levels were found to be depressed following routine work with mevinphos and methidathion. He had no subjective complaints, but his employer sent him for a physical. The examining physician noted the presence of miosis and salivation.*
308-85	ND	4.1	70.5	NA	1	*Mixer/loader hand poured mevinphos and methomyl and did not use appropriate personal protective equipment. After three days of general fatigue, he sought medical treatment for headaches, dizziness, muscle spasms, twitching of the eye, and vomiting. Pancreatitis noted during hospitalization may have resulted from organophosphate poisoning.*

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1982-1989 Cases Associated with Mevinphos Application (Exposure Class= 7+ 8)

ID	Primary Pesticide	CHE Data	% RBC Dep	% PLA Dep	Ill-Class	Comment
860-85	ND	4.2	67.9	74.7	1	*Mixer/loader had worked two months for a crop dusting service - with mevinphos, methamidophos, methomyl, and oxydemeton-methyl - when he developed twitching of the eye, numbness in the hands, and difficulty breathing. Examination of work records and CHE results revealed a steady decline in CHE, but no specific episode of direct exposure. He routinely used appropriate safety equipment, but reported occasionally removing his respirator when it became hot and uncomfortable.*
1784-85	MEVINPHOS	3.0	NA	NA	2	*Worker developed twitching of the eyes and pinpoint pupils after unloading open mevinphos containers at a formulation plant.*
1816-85	MEVINPHOS	4.2	67.0	84.4	1	*Mix/loader developed blurred vision, vomiting, weakness, and headache while loading mevinphos for an aerial applicator. Exposure may have occurred from periodic removal of respirator after loading plane. Field investigator speculated that residual mevinphos was trapped near the ground by an air inversion.*
1817-85	MEVINPHOS	4.1	48.6	90.5	1	*Coworker of 1816-85 sought treatment for comparable symptoms and had marked CHE depression.*
1818-85	MEVINPHOS	4.0	3.8	0.0	4	*Developed dizziness, nausea, chills while mixing mevinphos despite use of appropriate protective equipment and a closed loading system. CHE at time of illness showed no depression relative to baseline.*
2194-85	ND	4.0	0.0	0.0	4	*Worker developed vomiting, headache, and stomach ache after mixing and loading mevinphos and methomyl. Laboratory results showed normal CHE, abnormal liver enzymes, and positive IgM antibodies against hepatitis A.*
2221-85	ND	1.0	NA	NA	4	*Worker developed nausea, nervousness, and elevated heart rate after applying methamidophos, demeton, and mevinphos. He reported wearing "all safety gear" including a respirator. On the day of the incident CHE levels were reported higher than baseline.*
2367-85	ND	4.1	NA	63.5	1	*Newly hired applicator developed vomiting and headache after applying oxydemeton-methyl and mevinphos and other CHE inhibitors for approximately two weeks. Investigation did not document a specific direct exposure incident or failure to use appropriate protective equipment.*
2399-85	ND	4.1	49.5	50.3	1	*Employee developed nausea, blurred vision, abdominal cramping, headache, and weakness after mixing and loading methomyl and mevinphos without a closed system.*

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1982-1989 Cases Associated with Mevinphos Application (Exposure Class= 7+ 8)

ID	Primary Pesticide	CHE Data	% RBC Dep	% PLA Dep	Ill-Class	Comment
411-84	ND	4.1	70.5	71.7	1	*Worker had been mixing and loading mevinphos for several days when he developed nausea, sweating, and vomiting one evening after work. No specific direct exposure or failure to use protective equipment documented in investigation.*
1396-84	ND	4.1	87.5	92.7	1	*After spraying field with demeton, mevinphos, and diazinon, applicator developed a headache, blurred vision, and chest tightness, and began to vomit. Reported using appropriate safety gear.*
1469-84	ND	2.0	NA	NA	2	*Worker applied mevinphos, methyl parathion, and methidathion to artichokes on throughout the night he became ill; on arriving home from work he began to vomit. Low CHE levels noted, but specific values not available.*
1549-84	MEVINPHOS	2.0	NA	NA	1	*Worker with chronic exposure to organophosphates had acute inhalation exposure when stuck his head in a mix tank containing mevinphos, while wearing his respirator around his neck. He developed headache, vomiting, and blurred vision.*
2416-84	ND	4.1	86.7	86.4	1	*Mixer/loader experienced nausea, diarrhea and vomiting after loading a plane with several mevinphos and methomyl. Depressed CHE levels even though no specific direct exposure incident or failure to use appropriate safety equipment noted.*
2265-84	MEVINPHOS	3.0	NA	NA	3	*After spraying mevinphos on strawberry field, he began to feel nausea and dizziness, then began to vomit. He was treated with atropine but no CHE levels were measured. No specific exposure was noted. Coworker who was also ill speculated that illness may have been the result of food poisoning.*
280-82	ND	4.1	69.1	41.9	1	*Mixing and loading mevinphos, malathion and dimethoate, employee of crop dusting service wearing coveralls and gloves but no respirator. Possible exposure due to a leaking hose. He developed stomach cramps, weakness, and nausea.*
721-83	ND	3.0	NA	NA	3	*Mixing/loading and applying mevinphos and methomyl without protective equipment or closed system when he developed nausea, vomiting, and numbness.*
1990-83	MEVINPHOS	5.0	NA	NA	3	*Flagging in field being treated with mevinphos. Did not wear any protective clothing and had no safety instruction. Developed diarrhea and paresthesia during the evening.*

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1982-1989 Cases Associated with Mevinphos Application (Exposure Class= 7+ 8)

ID	Primary Pesticide	CHE Data	% RBC Dep	% PLA Dep	Ill-Class	Comment
2312-83	MEVINPHOS	4.1	81.9	85.4	1	*Mixing/loading mevinphos and lannate with full protective clothing and closed system. During the evening he became nauseated and began to vomit; medical evaluation showed both RBC and plasma CHE levels were depressed. Employer believes he may not have worn the respirator the entire work period.*
1015-83	MEVINPHOS	4.4	0.0	0.0	3	*Flagged in the morning, reportedly wearing full protective clothing, then worked in the shop for the rest of the day. Developed abdominal cramping, nausea, diarrhea and constricted pupils after work. CHE within normal range, but no baseline test reported.*
1195-83	MEVINPHOS	3.0	NA	NA	3	*Farmer did not wear his respirator while applying mevinphos and acephate. Developed nausea, vomiting, and dizziness and was observed in the hospital.*
1957-83	ND	1.0	NA	NA	3	*While spraying mevinphos, methomyl, and oxydemeton-methyl, employee developed progressively severe cough. Used respiratory protection and protective clothing. CHE levels were reported to be within normal range. Dr. felt symptoms were possbily secondary to respiratory irritation.*
1985-83	MEVINPHOS	4.1	61.3	33.3	1	*Employee loaded mevinphos through a closed system. At the end of the day, he felt dizzy, nauseous and vomited. CHE levels were markedly depressed.*
516-82	MEVINPHOS	3.0	NA	NA	3	*Four hours after mixing/loading (without closed system) and spraying mevinphos, worker became nauseous and began to vomit blood. Dr. treated patient with vitamins and testosterone.*
699-82	ND	2.0	NA	NA	1	*Applicator vomited once and sweated profusely after spraying mevinphos and methomyl. CHE reported below normal, but specific values not specified.*
1351-82	MEVINPHOS	5.0	NA	NA	3	*Developed nausea, vomiting and dizziness while hand-pouring residue from rinsed mevinphos containers into nurse tank.*
1531-82	MEVINPHOS	4.1	86.9	77.1	1	*Mixing and loading mevinphos, while wearing appropriate protective equipment, but developed symptoms of headache and vomiting. Medical records clearly indicate CHE inhibition.*
1532-82	MEVINPHOS	4.0	NA	10.8	2	*Coworker of 1531-82, developed drowsiness, difficulty breathing, abdominal cramps, and constricted pupils. Plasma CHE levels were within normal range; no baseline level established, and RBC CHE level not done.*

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1982-1989 Cases Associated with Mevinphos Application (Exposure Class= 7+ 8)

ID	Primary Pesticide	CHE Data	% RBC Dep	% PLA Dep	Ill-Class	Comment
1787-82	MEVINPHOS	5.0	NA	NA	3	*Developed headache and vomiting while spraying a field. CHE information not available.*
1810-82	ND	4.3	42.2	NA	1	*Applicator developed skin rash, nausea, drowsiness, and numbness on left side of the face after spraying mevinphos, methomyl, and fungicides on cherry tomatoes. No baseline CHE level, but followup of initial RBC CHE levels showed 42% increase.*

Drift Exposure

Drift exposure incidents accounted for 381 (65.9%) of the 578 cases in the study period, with 41 (10.8%) involving mevinphos as the primary pesticide and 340 (89.2%) involving mixtures of mevinphos and other cholinesterase inhibitors. Drift exposures demonstrated a significantly lower risk of definite illness than cases in the remaining exposure categories (RR={30/381}/{92/197}=0.17, $p<0.0001$). This negative association also held true for the subgroup of cases for with available cholinesterase data (RR={30/339}/{92/138}=0.13, $p<0.0001$). Drift exposures associated with exposure to mevinphos as the primary pesticide had a significantly higher rate of definite illness than the cases involving mixed exposures to mevinphos and other cholinesterase inhibitors (RR={16/41}/{14/340}=9.48, $p<0.0001$, by Fisher's exact test).

Mevinphos drift exposures were often associated with cluster illness incidents, which accounted for 355 (93.2%) of the 381 drift cases reported. The listing below gives a brief sample of the incidents by year and index case number, highlighting the episodes involving 20 or more cases:

Year/index case number	Comment
2756-87	*Workers harvesting/tying cauliflower could smell the odor (drift) from an application of fenvalerate, endosulfan, and mevinphos to an artichoke field 100-200 yards away during two separate incidents on 10/23 and 10/30/87. They complained of headache, nausea, burning skin & numbness. The illness investigation indicated cholinesterase values in the normal range on all 22 workers tested. Three additional workers had medical evaluation but not cholinesterase tests. Foliar sample for fenvalerate showed no detectable residue. No analysis for other chemicals was reported.*
1693-86	*An aerial application of ridomil, methomyl, mevinphos, oxydemeton-methyl and maneb drifted on to a school bus, with wipe samples showing residue levels ranging from 0.31 to 0.9 $\mu g/cm^2$ of oxydemeton-methyl. No analysis was conducted for mevinphos because of its rapid dissipation. All 25 individuals undergoing medical examination had normal cholinesterase values. One child (1721-86) developed a headache and nausea; other exposed children did not develop symptoms.*
771-85	*Twenty-two lettuce workers noticed odor from nearby application of vinclozolin, mevinphos, methomyl, and naled and reported symptoms of headaches and nausea. All workers had cholinesterase values in the normal range. Residue samples taken the day of the incident showed levels of vinclozolin ranging from 0.07 to 0.22 ppm of vinclozolin, but no detectable levels of mevinphos, naled, or methomyl. Analysis of clothing from*

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Year/ index case number	Comment
	two workers showed 0.05 and 0.40 ppm of vinclozolin and 0.06 and 0.11 ppm of naled, with no detectable residue of mevinphos or methomyl.
637-84	*Twenty-two lettuce workers noticed odor of adjacent application of mevinphos and pyrenone. Symptoms occurring in one or more workers included headache, nausea, vomiting, dizziness, fatigue, shortness of breath, and irritation of the throat. Plasma cholinesterase was within the normal range for all workers, but 16 (72.7%) had RBC cholinesterase below the lower limit of normal. Using the midpoint of the normal laboratory range as reference, the estimated RBC depression in this group of workers ranged from 20.3 to 37.4%. All cases originally classified as unlikely or unrelated to pesticide exposure, based upon absence of mevinphos residue in the field in which they were working. RBC depression interpreted as secondary to a previous exposure, the illness investigation did not identify a specific prior OP exposure incident. Residue samples taken the day of the incident showed 0.36 $\mu g/cm^2$ of mevinphos and 0.16 $\mu g/cm^2$ of diazinon..*
1470-84	*Thirty-eight lettuce harvesters began working in a field adjacent to a field treated with mevinphos, methomyl and maneb an hour earlier and noticed odor from the previous application. The 36 ill workers reported nonspecific symptoms compatible with OP poisoning ranging headache, nausea, dizziness, and difficulty breathing. Two workers reported no symptoms and two experienced only symptoms of eye and upper respiratory irritation. Cholinesterase tests indicated normal plasma and RBC cholinesterase activity for all but one worker who had RBC cholinesterase activity just below the lower limit of normal. Residue samples taken 12 hours following the exposure showed 0.26 ppm of mevinphos.*
1297-83	*Members of a crew of 135 broccoli harvesters noted a foul odor while working 1/8 mile from an aerial application of methamidophos, mevinphos, oxydemeton-methyl, and dimethoate. Foul odor was noted by a majority of the workers. Eighty-six developed symptoms ranging from nausea, vomiting, stomach pain, diarrhea, dizziness, shortness of breath, and eye irritation and 46 workers reported no symptoms. Insufficient information was recorded regarding the remaining three workers to determine the presence or absence of symptoms. Foreman sent all to hospital after working 15 minutes in the field. Cholinesterase tests showed normal RBC activity in 117 workers and activity below the lower limit of normal in eight workers. The remaining ten workers had no test results reported. Residue samples taken from the field on the day of the incident showed 0.2 ppm of methamidophos and 1.9 ppm of oxydemeton-methyl, but no detectable residue of mevinphos or dimethoate.*
2175-82	*A crew of 20 workers thinning brussel sprouts reported exposure to drift from application of methamidophos, oxydemethon-methyl, mevinphos, and dithane 1/8 of a mile away. Symptoms included headache, throat irritation, dizziness, numbness of the tongue and nausea. Seven had RBC cholinesterase activity below the lower limit of normal. Field residue samples taken the day of the incident showed 0.24 ppm of methamidophos and 0.2 ppm of oxydemeton-methyl.*

Field Residue Exposures

Field residue exposure cases accounted for 67 (11.6%) of the 578 cases with sufficient information to classify the illness-exposure relationship. By illness category the field residue cases included 30 definite, 22 possible, and 2 unlikely or unrelated cases. An additional 13 cases involved asymptomatic mevinphos exposures. A single cluster incident (index case 2095-82) accounted for 34 (50.7%) of the field residue cases and all but one of the definite illness cases. This episode resulted from entry into a cauliflower field treated 24 hours earlier with methomyl, mevinphos, and oxydemeton-methyl. Of the 34 workers who entered the field, 31 developed symptoms of eye and respiratory irritation as well nausea, headache, dizziness, nausea, vomiting, and weakness; the three remaining workers reported no symptoms despite the presence of definite cholinesterase inhibition. Twenty-nine (93.5%) of the 31 symptomatic workers had definite cholinesterase inhibition, with the estimated

degree of depression (compared to the midpoint of the normal laboratory range) varying from 29.5% to 77.2% for RBC and from 9.6% to 51.1% for plasma cholinesterase.

Miscellaneous Exposure Cases

This group of 11 cases derived from warehousing or formulation of mevinphos and repair of application equipment and one case of accidental ingestion of mevinphos contaminated broccoli. Mevinphos was classified as the principal pesticide exposure in six cases, with the four remaining cases involving mixtures of mevinphos with other pesticides. By illness classification, there were 1 definite case, 1 probable case, and 9 possible cases. The listing below gives a sample of the miscellaneous exposure cases:

1982-1989 Cases Associated with Miscellaneous Exposures to Mevinphos (Exposure Class = 10)

ID	Primary Pesticide	CHE Data	% RBC Dep	% PLA Dep	Ill-Class	Comment
1246-89	ND	4.0	0.0	0.0	2	*Nausea, vomiting, headache & weakness after 2 days of cutting & eating raw, unwashed broccoli. Pronounced bradycardia (44 - 48 beats/minute). Pesticide treatments of broccoli included mevinphos, oxydemethon-methyl, and fenvalerate. Cholinesterase tests showed normal levels of enzyme activity.*
1831-89	ND	4.1	87.7	88.9	1	*Dismantling airplane in field when illness developed. Materials formerly used in the plane included mevinphos, methamidophos, diazinon, and oxaymyl. Signs and symptoms included dizziness, abdominal pain, vomiting, nausea, bradycardia, diarrhea, slow slurred speech, and pinpoint pupils. Cholinesterase tests showed both plasma and RBC enzyme activity markedly decreased.*
57-87	MEVINPHOS	5.0	NA	NA	3	*Employee was packing mevinphos when he developed lightheadedness, followed by a headache. CHE blood test done, no results. No specific exposure was documented by investigation.*
1395-86	MEVINPHOS	5.0	NA	NA	3	*A warehouse worker mistakenly opened a can of mevinphos and developed symptoms of nausea, vomiting, eye irritation, and mental confusion. Treating physician drew cholinesterase tests, but the investigation report did not contain the results.*
2033-86	MEVINPHOS	5.0	NA	NA	3	*Employee was packing mevinphos all day. That night he ran a temperature with body aches, chills and vomiting. No investigation to confirm exposure--symptom relationship.*
645-82	MEVINPHOS	3.0	NA	NA	3	*Repaired loading pump without cleaning it first or using protective gear. All information gotten from interview of employer and hospital investigator unable to contact worker.*

Hospitalization

PISP files contained information regarding hospitalization on 540 (93.4%) of the 578 cases with sufficient information to classify the exposure-illness relationship, and 68 (12.6%) of these cases involved one or more days in the hospital. Sixty-seven spent between one to ten days in the hospital. The remaining case (1397-88, described above) spent 48 days in the hospital because of severe bradycardia and recurrent episodes of atrial fibrillation following a direct exposure to concentrated mevinphos.

The rate of hospitalization varied significantly by illness classifications (Table 8), with definite ($RR=\{52/117\}/\{16/423\}=11.8$, $p<0.001$) and probable ($RR=\{10/36\}/\{58/504\}=2.4$, $p=.009$, by Fisher's exact test) illness cases having a markedly higher rate of illness compared to the remaining categories. Possible cases, by contrast, had a markedly lower rate of hospitalization, compared to the remaining illness categories ($RR=\{5/250\}/\{63/290\}=0.07$, $p<0.001$), and no cases classified as unlikely or unrelated were hospitalized. The rate of hospitalization also varied significantly by exposure category (Table 9), with the highest rate of hospitalization occurring among the cases associated with worker exposure to field residues ($RR=\{29/66\}/\{39/474\}=5.34$, $p<0.001$) those associated with direct exposure to mevinphos ($RR=\{14/38\}/\{54/502\}=3.42$, $p<0.001$), and other application associated illnesses ($RR=\{21/74\}/\{47/466\}=2.81$, $p<0.001$). Cases associated with exposure to drift, by contrast, had markedly lower rates of hospitalization compared to the remaining exposure categories ($RR=\{1/351\}/\{67/189\}=0.01$, $p<0.0001$).

Lost Work Time

Cases involving one or more lost work days accounted for 201 (45.6%) of the 440 case records that contained information on disability (Table 10). As with rates of hospitalization, disability rates varied by illness category, with significantly higher rates among both the definite ($RR=\{77/108\}/\{124/332\}=1.91$, $p<0.0001$) and probable cases ($RR=\{21/32\}/\{180/408\}=1.49$, $p=0.01$) compared to cases in the remaining illness categories. Nevertheless, 73 (38.2%) of 191 possible cases and 5 (33.3%) of 15 unlikely/unrelated cases with known disability status lost at least one day from work.

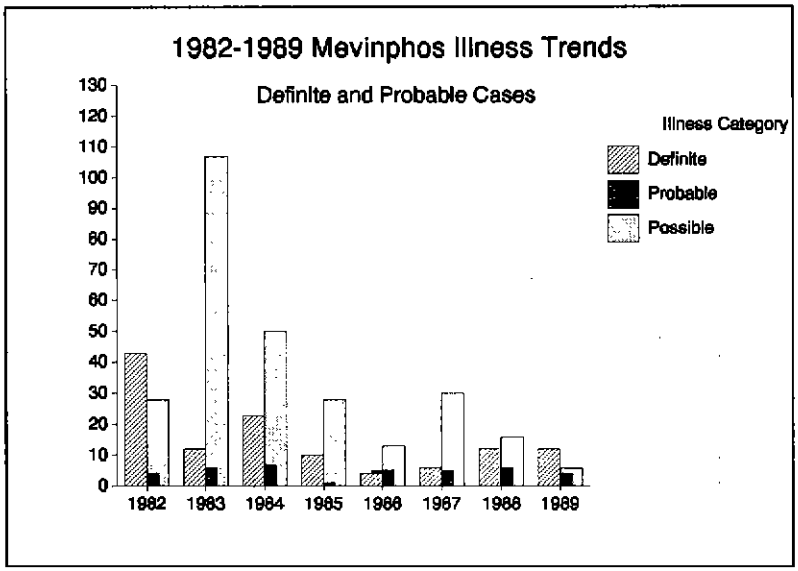

Figure 3

The rate of time lost from work (Table 11) differed slightly among categories of exposure, with the highest risk of lost work time occurring among direct exposure ($RR=\{20/31\}/\{182/412\}=1.46$, $p=0.044$), other application associated cases ($RR=\{44/59\}/\{158/384\}=1.81$, $p<0.001$), and field residue associated cases ($RR=\{47/65\}/\{155/378\}=1.76$). A significantly decreased risk of time lost from work was observed for the exposure cases ($RR=\{88/284\}/\{115/160\}=0.43$, $p<0.0001$), but these cases nevertheless accounted for 43.6% of the total lost-work-time cases.

Secular trends

Table 12 gives trends in illness associated with exposure to mevinphos by year and category of illness. As indicated in the table and inset figure 3, the peak year for illness assoicated with mevinphos exposures occurred in 1983, influenced by the large number of possible illnesses associated with a cluster of drift exposure (see reference case 1297-83). The peak year for application and direct mevinphos exposure cases (categories 1, 7 and 8) occurred in 1988 and 1984 (Table 13), but these cases occurred in each year of the study period. No apparent time trend occurred among the cases classified as possible illness (Table 10), and general trends discussed above also appear upon examining the subset of cases involving mevinphos as the primary pesticide exposure (Table 11) and those involving mixtures of mevinphos and other cholinesterase inhibitors (Table 12).

Discussion

Data limitations

Case records

Although the California PISP program offers a unique population based data source for evaluating the occurrence of pesticide illnesses, several limitations to the surveillance data deserve consideration. For cases that are reported to the system, complete understanding of the exposure-illness relationship is hindered by lack of routine access to medical records to obtain test results where the cholinesterase test was ordered, and by the apparent failure of physicians to order cholinesterase analysis for a portion of the cases. Reporting of symptoms in medical records, PIRs, and DFRs may also be incomplete, so that the presence or absence of critical diagnostic signs may have been incompletely recorded on the available records. Understanding of the circumstances of exposure may have been limited in some instances since disclosure of violations of closed system and respiratory protection requirements resulted in enforcement penalties. This limitation is specially critical in evaluating the 29 definite, 11 probable, and 10 possible illness cases in mevinphos applicators that occurred despite apparent adherence to existing regulations (Table 1). Although 26 (52.0%) of these 50 cases resulted from mixed exposure to mevinphos and other cholinesterase inhibitors (Table 4), the remaining 24 (48%) of the cases resulted principally from exposure to mevinphos.

Drift exposure

Drift exposure cases accounted for 65% of the total cases associated with mevinphos, resulting from a number of large cluster episodes of fieldworker illness. In each episode it was possible to infer some drift associated inhalation exposure from the results of subsequent foliage samples, but foliage residue measurements do not have any clear quantitative interpretation in terms of inhalation exposure and may underestimate the level of exposure at the time of the incident because the high relative vapor pressure of mevinphos[13] leads to rapid dissipation of foliar residue. The occurrence of definite cholinesterase inhibition following exposure to drift of mevinphos may indicate substantial inhalation exposure in some of those exposed. Definite inhibition was found in only 4.1% of cases involving mixed exposure to mevinphos and other cholinesterase inhibitors, and in some instances could possibly have been attributed to unidentified prior exposures to other cholinesterase inhibitor. By contrast definite depression was found in 39% of those primarily exposed to drift of mevinphos. This finding appears statistically significant, but all instances of definition inhibtion associated with drift of mevinphos *per se* were attributable to a single cluster episode . The high frequency of cholinesterase depression in that incident may have been attributable to unique exposure circumstances rather than undiluted exposure to mevinphos. Field investigators involved in the incident arrived at another possible conclusion - that the depression was attributable to an unidentified episode of prior exposure (reference case 637-84).

Illness reporting and mevinphos use data

During the period from 1982-1988 for which California sales and use data were available, there were 22,091,043 pounds of mevinphos reported sold in the state and 10,661,436 pounds reported used in 271,132 separate applications.[14,15] Although the use and sales data suggest that the vast majority of mevinphos applications were not associated with episodes of illness, this inference must be considered uncertain in light of the longstanding controversy regarding of the completeness of illness reporting to the California PISP system.[16,17]

Conclusions

The relevance of the California experience with mevinphos to agricultural workers in other states depends upon the similarity of farming practices and environmental conditions in other farming areas to those involving mevinphos use in California (Tables 6 and 7). Cases associated with application of mevinphos might be expected whenever a sufficient volume of the material is used, regardless of the specific crop. For states that do not require closed systems for mixing and loading mevinphos, additional cases might be expected.

The occurrence of drift and residue exposures to nonapplicators are less readily predicted. As this series of cases shows, significant residue exposure to mevinphos may be unlikely in the absence of a violation of reentry intervals. The rapid dissipation of mevinphos attributable to its relatively high vapor pressure presumably accounts for this finding. The high vapor pressure of mevinphos probably also accounts for its frequent association with episodes of drift exposure. Although only 30 (7.9%) of the 381 drift exposures demonstrated definite evidence of cholinesterase inhibition, these 30 cases present a contrast with the near absence of cholinesterase inhibition associated with drift exposure to other organophosphates, notably parathion.[18]

Table 1

Crosstabulation of Exposure and Illness Categories

	Illness Category					
Exposure Category	**1**=*Definite*	**2**=*Probable*	**3**=*Possible*	**4**=*Unlikely/ unrelated*	**7**=*No symptoms*	**Row Total**
1=*Direct eye/skin exposure*	20	17			5	**42**
2=*Drift exposure*	30	6	231	19	95	**381**
5=*Normal fieldwork*			6	2		**8**
6=*Reentry violation*	30		16		13	**59**
7=*Normal application*	29	11	10	3	3	**56**
8=*Safety violation*	12	2	6			**20**
9=*Ingestion*		1				**1**
10=*Other*	1	1	9			**11**
Total	**122**	**38**	**278**	**24**	**116**	**578**

Table 2

Crosstabulation of Exposure and Illness Categories
for Cases with Cholinesterase Information Present

	Illness Category					
Exposure Category				*Unlikely/*	*No*	**Row**
	1=*Definite*	2=*Probable*	3=*Possible*	4=*Unrelated*	7=*Symptoms*	**Total**
1=*Direct eye/skin exposure*	20	2			3	**25**
2=*Drift exposure*	30	6	200	18	85	**339**
5=*Normal fieldwork*			2			**2**
6=*Reentry violation*	30		11		10	**51**
7=*Normal application*	29	5	3	3	3	**43**
8=*No protective equipment*	12	1				**13**
9=*Ingestion*		1				**1**
10=*Other*	1		2			**3**
Total	**122**	**15**	**218**	**21**	**101**	**477**

Table 3

Crosstabulation of Exposure and Illness
Categories for Cases Involving Mevinphos as Primary Pesticide

	Illness Category					
Exposure Category	**1**=*Definite*	**2**=*Probable*	**3**=*Possible*	**4**=*Unlikely/ unrelated*	**7**=*No symptoms*	**Row Total**
1=*Direct eye/skin exposure*	11	13			1	**25**
2=*Drift exposure*	16	1	23		1	**41**
5=*Normal fieldwork*			**1**			**1**
6=*Reentry violation*			2			**2**
7=*Normal application*	12	5	7	1		**25**
8=*Safety violation*	4		5			**9**
10=*Other*		1	8			**9**
Total	**43**	**20**	**46**	**1**	**2**	**112**

Table 4

Crosstabulation of Exposure and Illness Categories
for Cases Involving Mevinphos and Other Cholinesterase Inhibitors

	Illness Category					**Row**
Exposure Category	**1**=*Definite*	**2**=*Probable*	**3**=*Possible*	**4**=*Unlikely/ unrelated*	**7**=*No symptoms*	**Total**
1=*Direct eye/skin exposure*	9	4			4	**17**
2=*Drift exposure*	14	5	208	19	94	**340**
5=*Normal fieldwork*			5	2		**7**
6=*Reentry violation*	30		14		13	**57**
7=*Normal application*	17	6	3	2	3	**31**
8=*Safety violation*	8	2	1			**11**
9=*Ingestion*		1				**1**
10=*Other*	1		1			**2**
Total	**79**	**18**	**232**	**23**	**114**	**466**

Table 5

Crosstabulation between Current and Former Illness Classifications[c]

	Current Category				
Former Category	**1**=*Definite*	**2**=*Probable*	**3**=*Possible*	**4**=*Unlikely/ unrelated*	*Total*
Definite	52	**14**	6		**72**
Probable	9	7	15	3	**34**
Possible	40	**15**	122	7	**184**
Unlikely/ unrelated	21	1	125	14	**161**
	122	**37**	**268**	**24**	**451**

c comparison excludes asymptomatic cases and cases not categorized in either current or former classifications.

Table 6

1982-1989 Mevinphos Cases by Crop

Crop	Cases	% of Total
Alfalfa	6	1.0
Almonds	1	0.2
Tree fruit	2	0.3
Vegetables		
Artichokes	12	2.1
Beans	1	0.2
Bell peppers	3	0.5
Bok choy	1	0.2
Broccoli	145	25.1
Brussel sprouts	25	4.3
Cabbage	1	0.2
Cauliflower	92	15.9
Celery	6	1.0
Cucumber	1	0.2
Eggplant	1	0.2
Green onions	12	2.1
Lettuce	96	16.5
Statice	2	0.3
Tomatoes	1	0.2
Vegetables, unspecified	1	0.2
Bermuda grass	2	0.3
Melons	5	0.9
Cotton	3	0.5
Grapes	13	2.2
Pistachios	1	0.2
Strawberries	5	0.9
Unspecified	138	23.9
Total	578	100.0

Table 7

1982-1989 Mevinphos Cases by
Standard Industrial Classification (SIC)

Industry	SIC	Cases	% of Total
Field crops, except cash grains	0139	3	0.5
Vegetables and melons	0161	281	48.9
Berry Crops	0171	4	0.7
Grapes	0172	6	0.5
Deciduous tree fruits	0175	2	0.3
Ornamental floriculture and nursery products	0181	4	0.7
General crop farms	0191	11	2.1
Soil preparation services	0711	1	0.2
Crop protection services	0721	81	13.8
Crop harvesting services	0722	59	10.1
Crop preparation for market	0723	3	0.5
Farm labor contractors	0761	39	6.7
General Contractors	1542	9	1.5
Wineries	2084	2	0.3
Agricultural chemical manufacturing	2879	10	1.7
General warehouse and storage	4225	1	0.2
Transportation services	4789	4	0.7
Electric services	4911	6	1.0
Gas and electric service	493	6	1.0
Water Supply Utility	4941	2	0.3
Elementary and secondary schools	8211	1	0.2
General government	9199	7	1.2
Police protection	9221	2	0.3
Fire protection	9224	2	0.3
Non-occupational		32	5.5
		---	-----
Total		578	100.0

Table 7a

Exposure Category by Standard Industrial Classification (SIC)

	Exposure Category								
SIC	**1**=*Direct eye/skin exposure*	**2**=*Drift*	**5**=*Normal fieldwork*	**6**=*Reentry violation*	**7**=*Normal application*	**8**=*Safety violation*	**9**=*Ingestion*	**10**=*Other*	**Row Total**
None		26		5	1				**32**
0139	1					2			**3**
0161	7	246	4	13	8	2		1	**281**
0171	1		1		2				**4**
0172	2				4				**6**
0175					2				**2**
0181	3	1							**4**
0191	1	8	1			1			**11**
0711		1							**1**
0721	20	5	1		38	15		2	**81**
0722		57	1	1					**59**
0723		3							**3**
0761		3		35			1		**39**
1542		9							**9**
2084		1			1				**2**
2879	3	1						6	**10**
4225								1	**1**
4789	4								**4**
4911		6							**6**
4931		6							**6**
8211		1							**1**
9199		2		5					**7**
9221		2							**2**
9224		2							**2**
Total	**42**	**382**	**8**	**59**	**56**	**20**	**1**	**10**	**578**

Table 8

Crosstabulation of Days Hospitalized by Illness Categories

	Illness Category					
Days Hospitalized	**1**=*Definite*	**2**=*Probable*	**3**=*Possible*	**4**=*Unlikely/ unrelated*	**7**=*No symptoms*	**Row Total**
0	65	27	244	21	115	**472**
1	33	4	2		1	**40**
2	6	5	2			**13**
3	6	1				**7**
4	3					**3**
5	2					**2**
7	1		1			**2**
48	1					**1**
Unknown	5	2	28	3		**38**
Total	**122**	**39**	**277**	**24**	**116**	**578**

Table 9

Crosstabulation of Days Hospitalized by Exposure Category

	Exposure Category								
Days Hospitalized	**1**=*Direct eye/Skin exposure*	**2**=*Drift*	**5**=*Normal fieldwork*	**6**=*Reentry violation*	**7**=*Normal application*	**8**=*Safety violation*	**9**=*Ingestion*	**10**=*Other*	**Row Total**
0	24	351	7	30	42	11		7	**472**
1	4			29	5	2			**40**
2	7				3	1	1	1	**13**
3					3	3		1	**7**
4	1	1			1				**3**
5	1				1				**2**
7						2			**2**
48	1								**1**
Unknown	4	30	1		1	1		1	**38**
Total	**42**	**382**	**8**	**59**	**56**	**20**	**1**	**10**	**578**

Table 10

Crosstabulation of Lost Work Days and Illness Category

	Illness Category					
Lost Work Days	**1**=*Definite*	**2**=*Probable*	**3**=*Possible*	**4**=*Unlikely/ unrelated*	**7**=*No symptoms*	**Row Total**
None	31	11	118	10	69	**239**
1-4	18	13	66	5	20	**122**
5-10	42	6	5		3	**56**
11-20	7	2	2		2	**13**
21-30	6					**6**
>30	4					**4**
Unknown	14	7	86	9	22	**138**
Total	**122**	**39**	**277**	**24**	**116**	**578**

Table 11

Crosstabulation of Lost Work Days by Exposure Category

	Exposure Category								
Lost Work Days	**1**=*Direct eye/skin exposure*	**2**=*Drift*	**5**=*Normal fieldwork*	**6**=*Reentry violation*	**7**=*Normal application*	**8**=*Safety violation*	**9**=*Ingestion*	**10**=*Other*	**Row Total**
None	11	194	2	16	13	3			**239**
1-4	12	79	5	7	11	6		2	**122**
5-10	2	2		35	13	3	1		**56**
11-20	1	2			6	3		1	**13**
21-30	4				2				**6**
>30	1				2	1			**4**
Unknown	11	105	1	1	9	4		7	**138**
Total	**42**	**382**	**8**	**59**	**56**	**20**	**1**	**10**	**578**

Table 12

Crosstabulation of Year of Illness by Illness Categories

	Illness Category					
Year	**1=*Definite***	**2=*Probable***	**3=*Possible***	**4=*Unlikely/ unrelated***	**7=*No symptoms***	**Row Total**
1982	43	4[d]	28	1	6	**82**
1983	12	6	107	10	59	**194**
1984	23	7	50	6	9	**95**
1985	10	1	28	4	16	**59**
1986	4	6	12		26	**48**
1987	6	5	30	2		**43**
1988	12	6	16			**34**
1989	12	4	6	1		**23**
Total	**122**	**39**	**277**	**24**	**116**	**578**

d - includes one case of direct/eye skin exposure that occurred 12/31/81 and first reported in 1982.

Table 13

Crosstabulation of Year of Illness by Exposure Category

	Exposure Category								
Year	**1**=*Direct eye/skin exposure*	**2**=*Drift*	**5**=*Normal fieldwork*	**6**=*Reentry violation*	**7**=*Normal application*	**8**=*Safety violation*	**9**=*Ingestion*	**10**=*Other*	**Row Total**
1982	4[e]	29	2	35	8	3		1	**82**
1983	8	177		1	5	3			**194**
1984	12	72	1	2	7	1			**95**
1985	2	34		13	5	4		1	**59**
1986	3	32	2	1	4	4		2	**48**
1987	5	30	2		3	1		2	**43**
1988	2	7		6	16	2		1	**34**
1989	6	1	1	1	8	2	1	3	**23**
Total	**42**	**382**	**8**	**59**	**56**	**20**	**1**	**10**	**578**

e - includes one case of direct/eye skin exposure that occurred 12/31/81 and first reported in 1982.

Table 14

Crosstabulation of Year of Illness by Illness Category
for Cases Involving Mevinphos as the Primary Pesticide

	Illness Category					
Year	**1**=*Definite*	**2**=*Probable*	**3**=*Possible*	**4**=*Unlikely/ unrelated*	**7**=*No symptoms*	**Row Total**
1982	3	4[f]	15			**22**
1983	5	4	8			**17**
1984	17	3	8		1	**29**
1985	3	1		1		**5**
1986	2	4	6		1	**13**
1987	4		2			**6**
1988	4	2	2			**8**
1989	5	3	4			**12**
Total	**43**	**21**	**45**	**1**	**2**	**112**

f - includes one case of probable illness that occurred in December, 1981 first reported in 1982.

Table 15

Crosstabulation of Year of Illness by Illness Category for Cases Involving Mixtures of Mevinphos and other Cholinesterase Inhibitors

	Illness Category					
Year	**1**=*Definite*	**2**=*Probable*	**3**=*Possible*	**4**=*Unlikely/ unrelated*	**7**=*No symptoms*	**Row Total**
82	40		13	1	6	**60**
83	7	2	99	10	59	**177**
84	6	4	42	6	8	**66**
85	7		28	3	16	**54**
86	2	2	6		25	**35**
87	2	5	28	2		**37**
88	8	4	14			**26**
89	7	1	2	1		**11**
Total	**79**	**18**	**232**	**23**	**114**	**466**

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